The Hope Device
Team 14
Midpoint Report
July 6, 2018

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Mechanical Engineering Design II 001
2018

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DISCLAIMER

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EXECUTIVE SUMMARY

The purpose of the project was to create, a useful product for a person with a disability, so we have decided to make the two crutches one for the left leg and second for the right leg. To start with the project, we found existing designs and generated the requirements from the client description. After that, we generated the engineering requirements, which will present in our design. The black box model and the functional model are also developed as well in this report. The report also includes the development of the system level and the sub-system level designs. In system level, a few existing designs were found which were related to our project. These existing designs helped us in the designing phase of the project. In the sub-system level of a project, all the main sub-parts of the project were identified, and their existing designs were found. These existing designs of sub-parts helped us in selecting the material for each sub-part.

Few designs ideas were generated for the design and from these designs, the final design was selected using the Pugh chart and decision matrix. The Pugh chart narrowed down the result from ten designs to top three designs. The decision matrix narrowed down the result from three designs ideas to one final design. The final design selected from the two methods was two crutches, one for the leg movement and second for the support of the body. A CAD model was developed for the defined design and each part was separately developed in CAD model. The design was implemented in SolidWorks, but will not be implemented because of body variations, because for each body, the product has a different dimension. The bill of material was provided to understand the implementation phase and with the help of BOM, this model can implement as well. There was a major change in design, that was done at the end of the project. The team decided to make one more component, which was given the name of support. This support was used as a middle part so that the body will not fall over or face any trouble while using the crutches. Two crutches and one middle support were enough for walking for a paralyzed person.

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1 BACKGROUND

1.1 Introduction

Physical challenges and disabilities create complex, influential, dynamic, multidimensional barriers which reduce, limit, and restrict the freedom of movement. An individual that has restricted body movement can walk around with some assistive support. The support could be a wheelchair or a crutch. The project required the team to develop a design that can support the person with a disability to walk around without the use of any wheelchair.

1.2 Project Description

The project was to make supporters for people who have foot paralysis or are injured and are unable to walk. The device will allow them to walk using their hands by holding the two different supporters that hold their foot. In this project, we developed a device name Hope Device, in the Hope Device, we developed two crutches and one support, these two crutches help the human body stand up and the support provides the assistance for walking. The two crutches have the cuffs to hold the legs tightly and properly grip the hands with the handle under the arms, and support wraps around the abdomen and a wheel present under it for easy walking.

1.3 Original System

There was no original system for the product we were developing.

> "This project involved the design of a completely new hope device system. There was no original system when this project began."

2 REQUIREMENTS

In this section, the requirements of the project will describe. There were two types of requirements considering for the project. One was customer requirements, provided by our client in the form of the project description and second was engineering requirements, obtained from the customer requirements.

2.1 Customer Requirements (CRs)

The customer requirements (CRs) were determined by the client and located in the project description and requirements. The following table indicates the requirements:

Table 1: Customer Requirements

Customer Requirements
1. Easy to use/Flexibility
2. Affordability
3. Light-Weight
4. Low physical strain
5. Comfort and convenience
6. Low repairs & maintenance costs
7.Quality performance
8.Durability
9. Aesthetic design
10. Indoor & outdoor operation suitability

The next section indicates the engineering requirements.

2.2 Engineering Requirements (ERs)

The engineering requirements were derived from the customer requirements. They comprise the technical requirements of the project and have targeted values. The engineering requirements were present in Table 2.

Table 2: Engineering Requirements

Engineering Requirements	Target Values
1. Costs under $150	$150
2. Weight	5 Kg
3. Lifting capability of user	5 Kg
4.Appropriate price for spare parts ($40)	$40
5. Height of Device	2 m
6. Radius of leg knobs	0.3 m
7.Minimum changes in regular crutches	3
8. Round edges	0.2 m radius
9. Wheel radius	0.1 m
10.Maintenance cost between ($50)	$50

The team met with the TA for Senior Design 1 class, Mr. Jeremy, and he recommended the materials to use and gave us some useful sites to find the information that we were looking for. He also advised us to use tolerances for each part, such as for manufacturing, to be around $50. Then, we got these values which are presented on the above table based on the research that conducted. The estimated cost for spare and manufacturing parts estimated based on the material that we were using such, as the aluminum and the foam that suits our needs. The testing procedures of each engineering requirement were present in the next section.

2.3 Testing Procedures (TPs)

Engineering requirements were the technical requirements which need to be tested and the process of testing for each requirement was present below. The testing procedures were based on the SolidWorks Finite Element Analysis. The force and weight will be added to the design.

1. Total Cost
   Cost of this product was tested when all the items have been purchased. The sum of the cost spent on the implementation of product to identify the total cost.

2. Weight
   Weight is a physical quantity and was measured through weight scale, so testing of weight can be done by measuring the weight of product at the end.

3. Lifting Capability
   Capability to lift the product was test when it was implemented, and when the user will lift the product and test it.

4. Appropriate price for spare parts
   Spare parts price was determined in the market and see if the part available was lesser $40 or not.

5. Maneuverability
   The capability of holding the product easily and comfortably in the hands. This test was performed by holding the product in hand.

6. Stability
   Stability was an important factor to test. This was tested by applying the pressure to the product and see if it will topple over.

7. Minimum changes in regular crutches

Minimum changes was tested on the product when it is in use and see if the device needs to have any changes.

8. Safety
   Safety was important because if the device was not safe to use, then it will hurt the user. There must not be any sharp edges on it and must not topple over. Safety was tested by touching all the sides of product and see if there was an edge that can hurt the user.

9. Instant fitting and Removal
   This was tested by assembling and disassembling the product to see if it was quick or not.

10. Maintenance cost
    Maintenance cost was important for any device and for this device maintenance must not be over $50. This was tested by determining the maintenance it will require after wearing the product. The equipment that was required were the spare parts for the crutches. The spare parts were obtained from the hardware outlets. The testing of the crutches was done through the actual use by the physically challenges individuals. They have to offer feedback on the flexibility and comfortability of the crutches to adopt effective changes.

2.4 *House of Quality (HOQ)*

Information presented in the HOQ illustrates the performance quality and competitiveness of the crutches that we had proposed for development under the Senior Design - I with other brands that were currently marketed.

Table 3: House of Quality

Engineering Requirements / Customer Requirements	Importance	Cost	Weight	Lifting Capability of user	Spare parts availability	Height of Device	Radius of leg knobs	Minimum changes in regular cr	Round Edge	Wheel Radius	Maintenance cost	
User Friendly	3	3	3	9	1	3	1	3	1	3	3	
Affordability	3	9	3	3	9				3	1		
Light Weight	3		1	1	1	1	3	1		9	1	
Low physical Strain	3	9	9	3				9	1	3		
Increased comfort and convenience	1	1	1	1	3	3	3	1	3	3	3	
Low repairs and maintenance costs	3	1	3	9	1	3	1	3	1	3	3	
Quality performance	1	9	3	3	9				3	1		
Durability	1		1	1	1	1	3	1		9	1	
Aesthetic design	3	9	9	3				9	1	3		
Indoor and Outdor operation suitability	3	1	1	1	3	3	3	1	3	3	3	
Technical Importance: Raw Score		106	92	92	58	34	30	80	36	88	34	
Technical Importance: Relative Weight		**16.3%**	**14.2%**	**14.2%**	**8.9%**	**5.2%**	**4.6%**	**12.3%**	**5.5%**	**13.5%**	**5.2%**	
Techanical Target Value		150	5	5	40	2	0.3	3	0.2	0.1	50	
Upper Target Limit												
Lower Target Limit												
Units		$	Kg	Kg	$	m	m	-	m	m	$	

Based on the results of HOQ, the most important criteria were cost, that must be low and after was weight and lifting capability. And the least important engineering requirement was radius of leg knobs. Therefore, it can state that HOQ has provided us the engineering requirements priority order list.

3 EXISTING DESIGNS

In this section, some of the existing designs will present. Existing designs were those which are implemented already, and this was determined through the research. Existing design does not mean we were not producing the original product. Existing design means similar concepts which currently exist and the reason for searching these designs was to take some help from them while implementing the project. The next thing was searching for existing designs for the subsystem level. There were few sub-system levels of the project, and their existing design will search as well to take the help in our project.

3.1 Design Research

Information and knowledge gained from existing designs and product features of the assistive devices that were marketed under various internal brands were used for making our prototypes more suitable, perfect and satisfactory. The research was done over the internet and few existing designs have been found for the system level designs and the sub-system levels. The research was important in determining the actual requirements for developing the stretcher assistive devices. Also, the data offers a good explanation of the needs of the individuals who have immobility challenges. For example, they require assistive equipment that was flexible, durable, affordable, and comfortable.

3.2 System Level

On a system level, we have determined few concepts which were related to our project and these design concepts helped us implement the project. Existing designs which have found are:

- Underarm Crutches
- Exoskeleton
- Walker Crutches

3.2.1 Existing Design #1: Underarm Crutches

Crutches were good for people who like using underarm crutches. This is because they were designed to compensate for the disadvantages of Forearm crutches. The disadvantage to using underarm crutches and crutches, in general, was that they rely on the strength of the user to use them correctly and they can be difficult to use in rainy or snowy weather.

Figure 1: Underarm Crutches [2]

3.2.2 Existing Design #2: Exoskeleton

The Exoskeleton is a work-in-progress device that was being developed at North Carolina State/University of North Carolina-Chapel Hill Department of Biomedical Engineering. The researchers believe that this will help people with paralysis, or trouble walking, overcome their disability. The current version of the device has resulted in an additional benefit of reducing the amount of energy required when using the device by seven percent. Another advantage was the light-weight aspect of the device, as it feels about the same as wearing a loafer on your foot. The biggest disadvantage of this device was that it was not fully tested, and the results were inconclusive for the time being.

Figure 2: Exoskeleton [3]

3.2.3 Existing Design #3: Walker Crutches

The Walker Crutches offers the benefits of using crutches base which help the user to aid the balance in walking. This device requires less strength which provide comfortability in usage. The disadvantage of this device was the difficulty to use for some people who stand at full height.

Figure 3: Walker Crutches [4]

3.3 Functional Decomposition

The functional decomposition illustrated the effectiveness of the proposed models in enhancing the mobility of the disabled individuals. There were two effective and efficient models which were the Black Box Model and the Functional Model. The Black Box Model presents material, function and flow of the project. It also aimed to enhancing the performance of the device, to enhance the mobility of the individuals with paralysis. The Functional Model illustrates the Black Box Model.

3.3.1 Black Box Model

The Black Box model, shown below in Figure 4, was created to imply the fundamental capability of disabled people who can walk normally by our proposed design. In this Black Box, the bold line was defined as the material in this model; a thin line was used to state the energy for this model, and spotted line to identify the signal. The importance of this model was to show the functionalism of this device keeping in mind to reach the goal, which was to help individuals with paralysis walk like normal people. We appropriated the fundamental elements of the hope device by making this model and can be comprehended when having the budget and data sources.

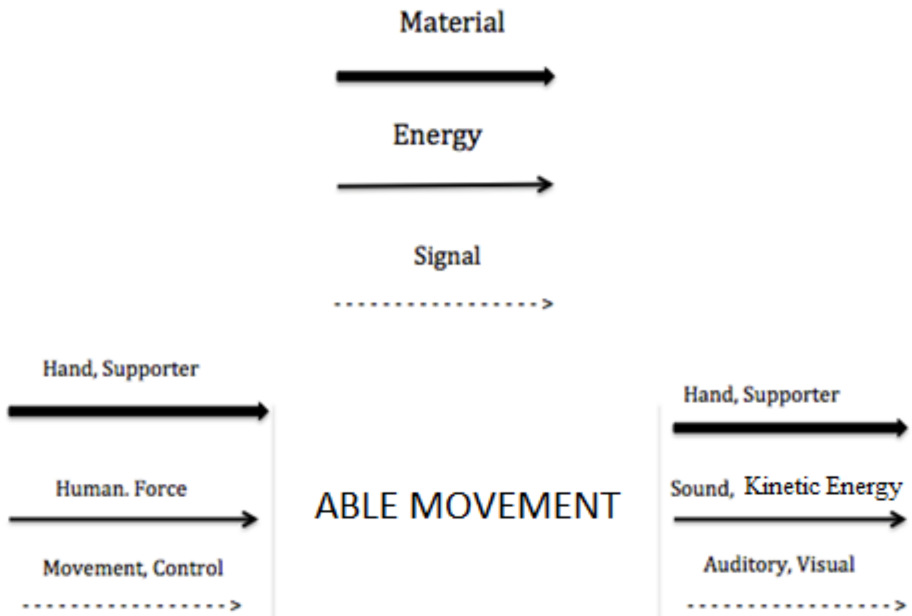


Figure 4: Black Box Model

3.3.2 Functional Model

The hypothesized Functional Model shows the complete working of any project, as it has the main function, material, energy, and sound. The functional demonstrates the flows and main functions for the hope device. The Hypothesized Functional Model indicates sub-functions, functions and flows that the hope device contains. The main function used in the Black Box model was Able Movement, which can be designated as the final function of the hope device. This function related to customer needs in one way or another. The functional model was important as the team learned how to divide product into functions and flows that were more accessible to the customer needs. Figure 5 indicates the relationships of various items and concepts in the Functional Model.

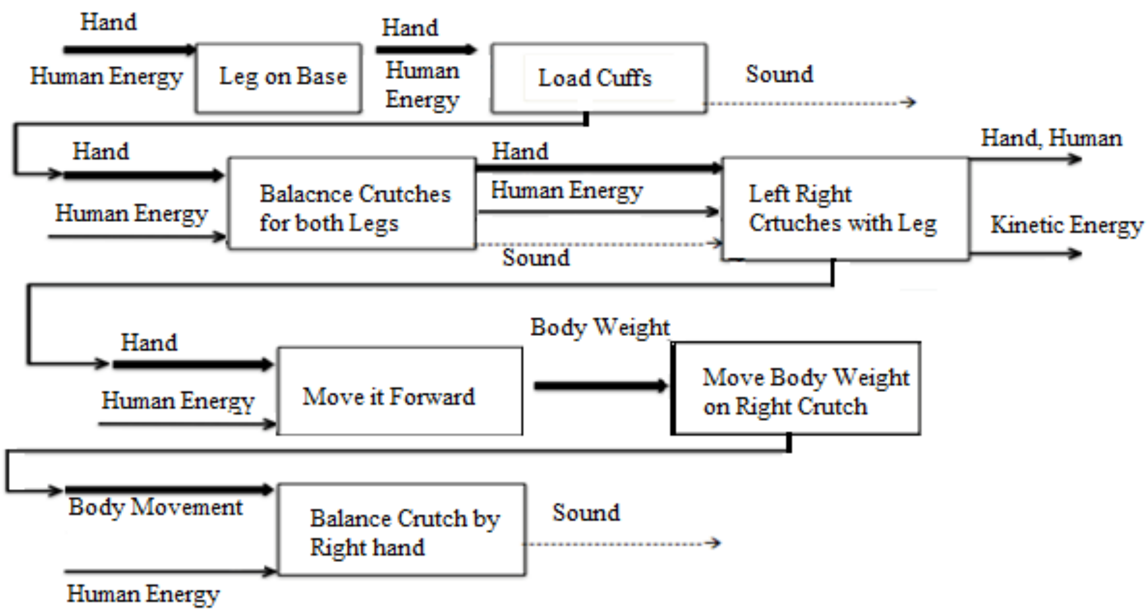


Figure 5: Hypothesized Functional Model

3.4 Subsystem Level

In sub-system level, there were three sub-systems considering in the report. The basic sub-systems that were considering here are:

- Holder
- Legged supports
- Base

3.4.1 Subsystem #1: Holder

The holder was the main part of the project which provided the support to carry the crutch. The individual will insert their hand into the holder and will get the support from it. Three existing designs have found for the holder which have presented below.

3.4.1.1 Existing Design #1: Steel Holder

The steel holder is already available and could be used in our project as well. The holder can be made from any material, but the steel holder was strong and able to bear a lot of pressure applied by the user as show in the figure below.

Figure 6: Steel Holder [5]

3.4.1.2 Existing Design #2: Wooden Holder

Another existing design was the wooden holder which could also be used in our project. The wooden holder was strong and heavier as well, but it can use in our product because it has the capability to bear the pressure as well.

Figure 7: Wooden Holder [6]

3.4.1.3 Existing Design #3: Plastic Holder

Another existing design available for the holder was the plastic holder. Plastic holders are lightweight and can bear only a limited weight but could still be used in our project. The holders were affordable to acquire, and they enhanced the comfort level of the person as they were soft in texture. Also, they were not affected by frequent weather changes as they were not good conductors of the environmental heat. Therefore, they were comfortable in both hot and cold weather conditions.

Figure 8: Plastic Holder [7]

3.4.2 Subsystem #2: Legged Supports

Legged support was another sub-system level which will cover the leg and carry the load of the body.

3.4.2.1 Existing Design #1: Round Legged Support

Round legged support was an existing design of our project. In this design, the covering of leg will be done by the round shape support and it can be used in our project as well. It is showing below in figure 9. The support improves the stability of the device and the comfort of the user.

Figure 9: Round Legged Support [8]

3.4.2.2 Existing Design #2: Square Legged Support

Another existing design was the square legged support which could be used in our project. Square legged support can hold the legs easily as well. As a result, there was stability and firm connection between the legs of the person and the assistive device.

Figure 10: Square Legged Support [9]

3.4.2.3 Existing Design #3: Open Ended Legged Support

Open-ended legged support could also be used in our project for holding the legs, but it will have the open end which will not be able to carry the leg easily. It is shown in Figure 11.

Figure 11: Open Ended Legged Support [10]

3.4.3 Subsystem #3: Base

The base was another sub-system of our project which can be in any form and it provides the support to the legs and the product.

3.4.3.1 Existing Design #1: Steel Base

An existing design for the base was available which can use in our project as well. The steel base was strong and capable of holding the complete weight of use and device as shown below in the image.

Figure 12: Steel Base [11]

3.4.3.2 Existing Design #2: Wooden Base

The wooden base could also use in our project. The wood is a strong base and can easily bear the weight of user and product as well.

Figure 13: Wooden Base [12]

3.4.3.3 Existing Design #3: Aluminum Base

The aluminum base is strong and has the capacity to carry the load as well. This base could also be used in our project. The aluminum base is shown in Figure 14. The base enhances the stability of the assistive device during movement.

Figure 14: Aluminum Base [13]

4 DESIGNS CONSIDERED

A few design ideas were generated for the project to select the final product. These designs are shown below.

4.1 Design # 1: Two Wheeled Walker

The two-wheeled walker offers the benefits of using wheels to make walking smoother as well as a seat for the individual to sit on when they become tired. This device makes it easier to go long distances when walking due to the leg base and the smooth of the wheels which is presented by the drawback feature. In addition, it requires less body strength for its use. The disadvantage key of this device was the difficulty to use for some people who stand at full height, the wheels can spin out of control which can cause accidents..

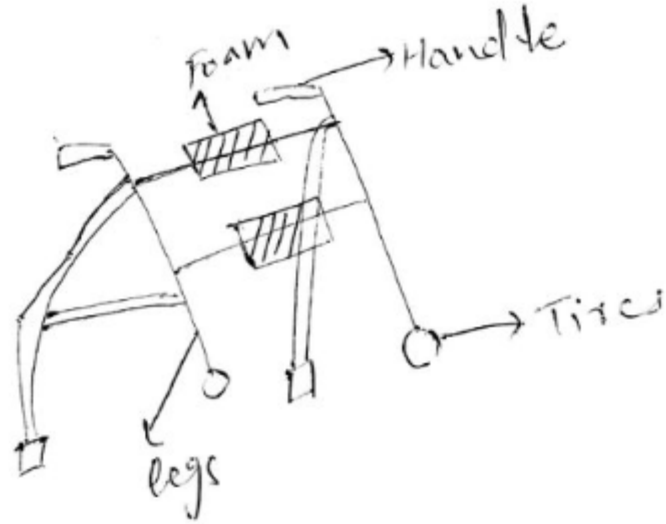


Figure 15: Design 1

4.2 Design # 2: Forearm Walker

Forearm crutches are a good alternative for people who do not like using underarm crutches. This was because they were designed to compensate for the disadvantages of underarm crutches. They provide a more ergonomic position of the hand and wrist, they allow for improved agility and walking speed, they were easier and safer to use when ascending and descending stairs, and they allow for a variety of walking styles. The forearm crutches rely on the strength as it will be difficult to use in some weather conditions like rain and snow.

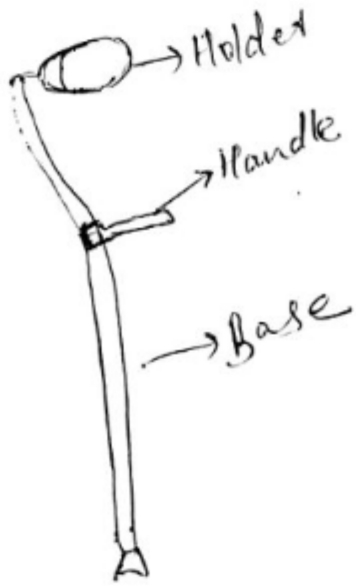


Figure 16: Design 2

4.3 Design # 3: Quad Cane Walker

The quad cane has been around for a while now. They offer many benefits to walking and those who have a difficult time doing so. Some of the benefits include: reducing knee, ankle, hips and spine stress, they strengthen muscles that support the spine, and it helps the upper body muscles to put off stress in wrists, forearms, hands, shoulders and elbows as well as in the neck. Quad canes do have their disadvantages though. Some of these include: getting stuck in the cracks of the pavement and repetitive strain can become a problem after using the cane too much.

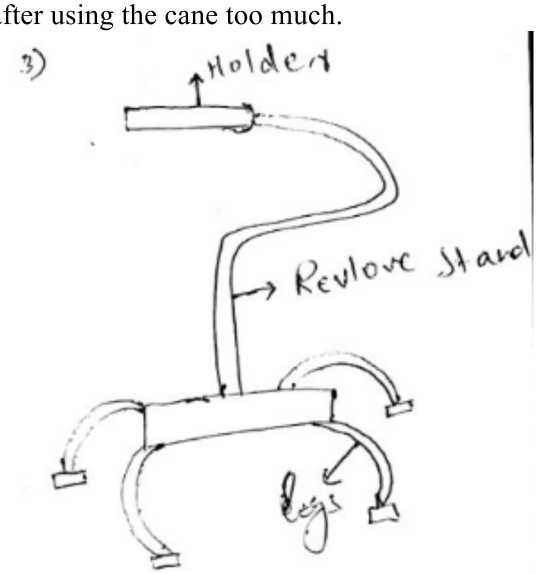


Figure 17: Design 3

4.4 Design # 4: Add-on Exoskeleton

The Add-on Exoskeleton is developed version of Exoskeleton that was a work in progress device that was being developed at North Carolina State/University of North Carolina-Chapel Hill Department of Biomedical Engineering. The main idea of this design is to improve it and make it lighter weight and add safety feature as the brace will protect the body. The current version of the device has resulted in reducing the amount of energy required when using to device by seven percent. The main disadvantage to this device was that it was not fully tested, and the results were inconclusive for the time being.

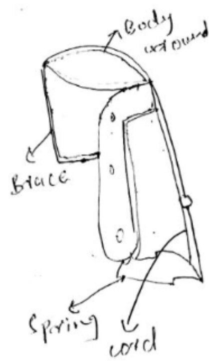


Figure 18: Design 4

4.5 Design # 5: Rebound Crutch

Underarm crutches have been around for over a hundred years for the purposes of helping people to walk. However, they have not always provided the best option for walking. The rebound crutch was a design that has many benefits. They are easy to use, provide improved comfort over the traditional crutch design, improve the posture of the user, and allow for a variety of walking styles. The cons of using underarm crutches were that they can cause armpits to be rubbed raw and they can cause major wrist pain.

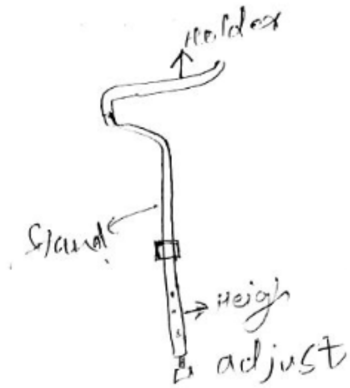


Figure 19: Design 5

4.6 Design # 6: Walking Frame

The walking frame was a relatively new form of technology that was based on the classic rolling walker. This device offers many benefits to those who were having difficulties walking or they cannot walk at all. It was designed with adjustable height handles and supportive mechanisms, which help relieve stress and pain in the back. Other beneficial aspects of its design include a foldable support, wheels, and moveable handles so that the user can use it as comfortably as possible. The biggest disadvantage was the cost, and that was because it was at the upper limits of what was affordable, and most people would prefer a cheaper option.

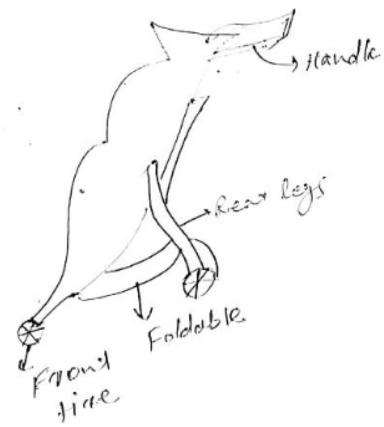


Figure 20: Design 6

4.7 Design # 7: Swap Design

In this design the concept was showing that a handle with the main support, and a support was showing around for making it strong.

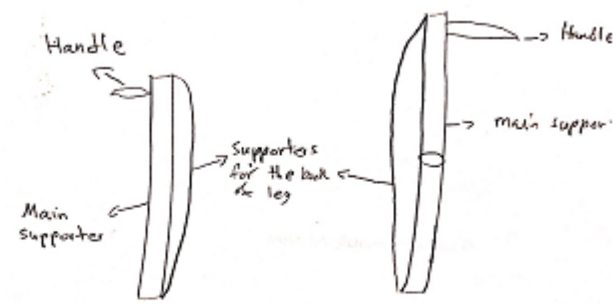


Figure 21: Design 7

4.8 Design # 8: Handle and Cap Stand

The design was showing in the figure in which the idea was to keep the stand straight and holding it up.

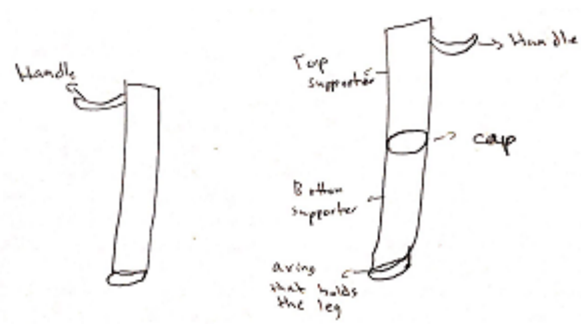


Figure 22: Design 8

4.9 Design # 9: Double Cap stand Design

It was similar to the above design, but it has two different caps to support the legs, shown below in Figure 23.

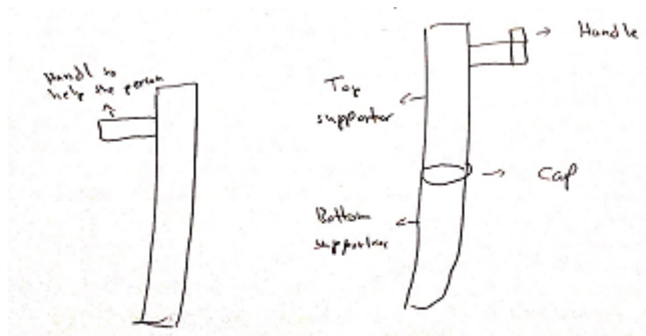


Figure 23: Design 9

4.10 Design # 10: Two-Legged Design

The idea was that there were two legs support and both supports were different from each other. According to the current design one leg will have three caps to hold the leg and second will have the two cups to hold the leg. The idea was showing below in Figure 24.

Figure 24: Design 10

5 DESIGN SELECTED – First Semester

For selection of any design there were difference methods which must use to select the final design. The reason for using these methods was that these methods evaluate the design according to the requirements of clients and without the evaluation of design it was difficult to select the design which fulfill all the requirements. That is why different methods use for selection of final design and in this section these methods will apply to the generated design and select the final design.

5.1 Rationale for Design Selection

To select the final design, we utilized two different methods, from these two methods the final design has obtained. These two methods are:

- Pugh Chart
- Decision Matrix

5.1.1 Pugh Chart

The Pugh chart was the tool that analyzes the designs below which were manual method, morph concept and bio inspired design. The Pugh chart was an important tool for designing project as it shows the importance of the sum criteria for each design and analyzes each one. It also gives the team members the insight to analysis the application of the criteria for the three designs in this Pugh chart.

Table 4: Pugh Chart

10 Designs	**Weight**	**Design # 1:**	**Design # 2**	**Datum Design**	**Design # 3**	**Design # 4**	**Design # 5**	**Design # 6**	**Design # 7**	**Design # 8**	**Design # 9**	**Design # 10**
Cost	8	+	+	D	-	+	-	-	-	+	+	+
Durable	7		+	D	+	-	+		+	+	+	+
Aesthetics Design	6	-		D	+	+	-	-		+	-	+
Affordable	5	+	+	D	-	+	-		-	-	-	+
Safety	4	+	-	D	+	S	-	+	-	+		+
Stable	3	+	+	D	+	-	+	-		+	-	+
Low Physical Strain	2	-	+	D	+	+	-	-	-	+		+
Light-Weight	1	-	-	D	-	-	+	-	-	+	+	+
Pluses		4	5	-	5	4	3	1	2	7	2	8
Minus		3	2	-	3	3	5	5	4	1	4	0

The Pugh chart produced the top three designs which were used in the decision matrix. Designs 2, 8 and 10 led to the final design, which was obtained based on the decision matrix calculations and results. The Pugh Chart ensures that the details of the final design adhere to all set criteria and in appropriate levels.

For example, the final design had the highest standards of safety and durability. Also, the design was aesthetically appealing and affordable to purchase and maintain.

5.1.2 Decision Matrix

The decision matrix was done by taking the top three designs from Pugh chart. In a decision matrix, each design was evaluated on the requirements and each design obtained a mark out of 8 and that marks were multiplied with weightage. The sum up all the values is used to determine which design has obtained maximum marks and that design became the final design.

Table 5: Decision Matrix

Decision Matrix	**Cost**	**Durable**	**Aesthetics Design**	**Affordable**	**Safety**	**Stable**	**Low physical Strain**	**Light –Weight**	**Total**
Weight	8	7	6	5	4	3	2	1	
Design # 2	6x8=48	6x7=42	2x6=12	7x5=35	7x4=28	5x3=15	5x2=10	2x1=2	192
Design # 8	7x8=56	6x7=42	4x6=24	7x5=35	7x4=28	5x3=15	5x2=10	3x1=3	210
Design # 10	8x8=64	5x7=35	5x6=30	7x5=35	6x4=24	6x3=18	7x2=14	5x1=5	225

From the decision matrix, the final design obtained was design #10, which was the two-legged support walker. The design had the highest score, which indicates satisfactory adherence to the important criterion and characteristics of the assistive device.

5.2 Design Description

The group decided to make supporters for people who have challenges of walking due to foot paralysis or injuries. The device enhances mobility by enabling the hands to hold the two different crutches that were attached to legs. Therefore, the person who uses the assistive device must be strong enough to lift the whole-body weight using hands.

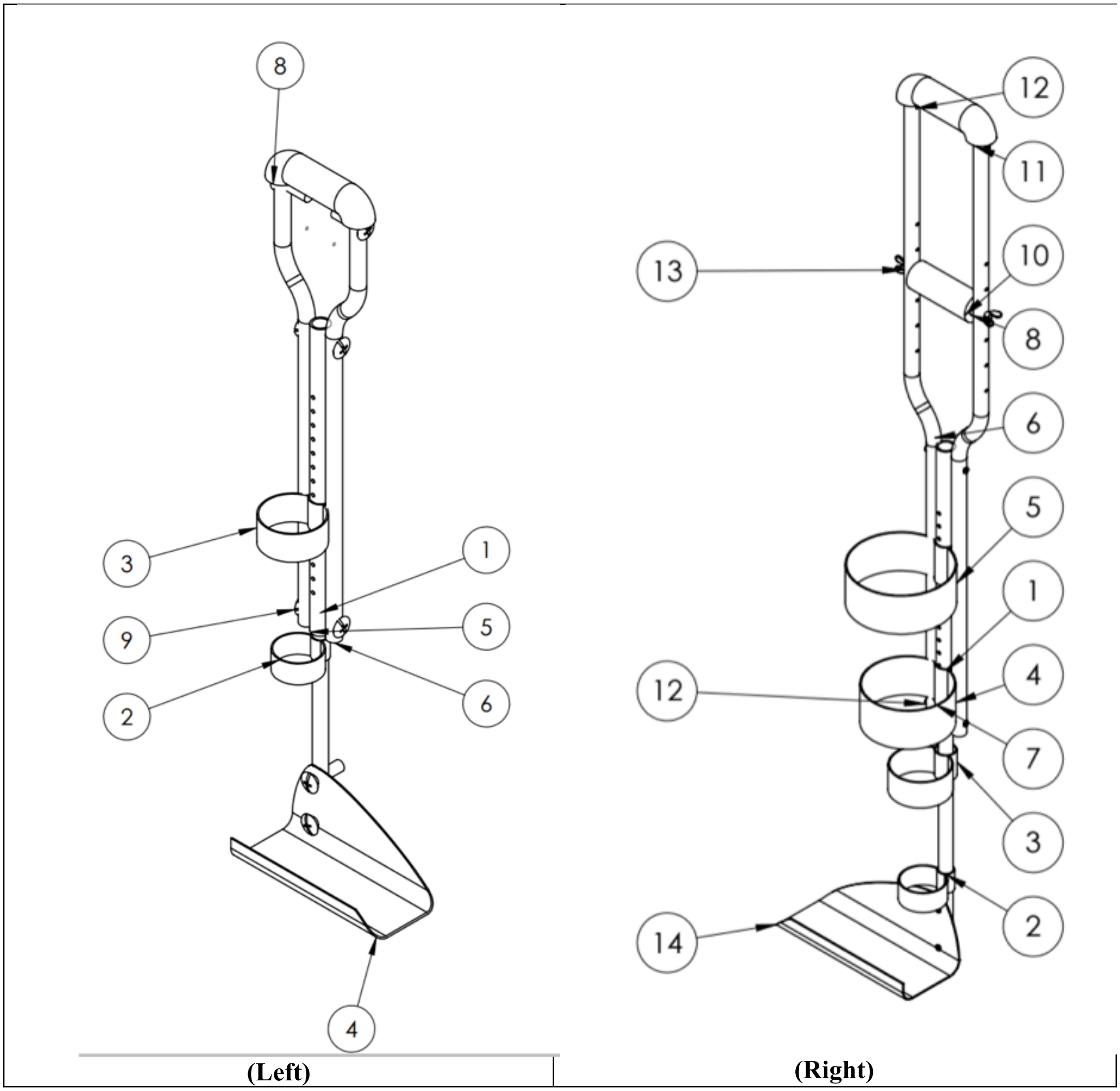


Figure 25: Assistive Device under Senior Design Project – I Prototype Development

Several Key Success Factors (KSFs), were taken into consideration in making the final selections of both the Left Crutch and the Right Crutch. The following were some of the most important technical features, which make these crutches most suitable, convenient and useful:

- Crutches work with users' physical strengths and powers, which have eliminated the need for attaching any mechanical support.

- Lack of built-in mechanical instruments, tools and applications enabled the crutches to remain light-weight, which does not cause any stress or strain even when the device users remain on their support for prolonged duration.

- Foot-rest flat base helps users to reduce impacts of bearing total body weight under the supports of the forearms and the armpits.

- Simplicity of the design allows users to wear and remove the device dozens of times according to their needs, demands, and requirements without the least efforts, strains and stress.

- Crutches were made with simple engineering technology applications that provided a safe and secured manual user support, which makes them quite inexpensive.

- Absence of mechanical devices or moving parts, made these crutches durable while eliminating expensive repairs, maintenance and repurchase costs or expenditures.

The Assistive Device, under the prototype development, contains a set of 2 Crutches, which could fit both the left and the right leg of the physically challenged person. The crutches were designed with a flat base at the bottom for foot rest, which provided added comfort, support and convenience to the users in minimizing, reducing and eliminating physical exertions while walking around with the device.

5.2.1 Left Crutch

Disabled and the physically challenged persons who were using the Left Crutch were users who were required to take the major load of their physical weight from being transformed onto the device. To facilitate their needs, requirements and expectations, the Left Crutch has been designed with the following technical features:

- Hand Grip &
- Crutch Pad

By supporting body weight on the Crutch Pad and reducing additional load through strong Hand Grip, users can maintain their leg position without flexing it. Due to substantial distribution of body weight through both Hand Grip and Crutch Pad, device users were able to enjoy prolonged outdoor walking or moving around in the indoor environment such as climbing-up or down long staircases without any strain, discomfort, inconvenience and exhaustion. However, the Left Crutch device users were required to be in strong physical fitness with good amount of stamina and strength as they need to continuously maintain their body load under their arm pit and the hand that rests on the Crutch Pad. Foot-rest flat base provides ideal and critical support in reducing weight bearing problems and challenges.

5.2.2 Right Crutch

The design for the Right Crutch, had been significantly modified to allow the disabled and the physically challenged persons to flex their legs. Leg flexing was supported and facilitated by the following device features:

- Shin &

- Calf

The device users were provided with Hand Grip, which enables them to maintain their postures and memorability while moving around in the outdoor or the indoor environment. Hand Grip provides added safety and security while also serving to assist device users in significantly reducing excess body loads onto the crutches.

6 PROPOSED DESIGN

In this section we were going to explain about the proposed design with all the details that will use to implement the design. First of divide the parts into sub-parts as:

- Cuff 1
- Cuff 2
- Cuff 3
- Cuff 4
- Handgrip
- Bended Under Arm Stick
- Stick
- Under Arm
- Hand Grip Foam
- Under Arm Foam
- CR-OHMS 0.216-28x1.25x1.25-S
- 1.25x0.25,Wing Screw,Type B,Style 2,Cup Point-S
- Leg Base R

Above sub-parts were for the hope device in left, now the hope device for right side have divided into sub-parts as:

- Cuff 1
- Cuff 2
- Lower Stick
- Stick
- Leg Base L
- Handgrip
- Bended Hand Grip Stick
- Under Arm
- Under Arm Foam
- CR-OHMS 0.216-28x1.25x1.25-S

The cuffs hold the device with the leg. There were different sizes, based on where will be attached. The handgrip was basically the main part to hold and control the device. The lower sticks and the upper sticks were connected to each other to adjust the length of the device and it was attached with the cuffs and hold the leg. The upper stick underarm and the upper stick hand grip were to balance the body on the device and to help controlling the device.

The implementation of this design was possible to do using the bill of material that found in appendices A explaining the material which were going to use for each part.

6.1 Bill of Materials

The bill of materials (BOM) is present in the Appendix A and includes all the material that we use for the implementation and their dimensions have presented as well. This BOM will use for the implementation and each material will purchase according to the given bill of material.

6.2 Manufacturing

The team implemented the design in SolidWorks, but the process of manufacturing was presenting in this section. First, this product will implement in the following way:

- Cuffs will develop at first with rubber to make the comfortable grip.
- Stick will develop with the Aluminum.
- Handgrips will make with aluminum and cover with the foam to provide the lightweight and durability of the device.

For manufacturing this product size of aluminum sheet was 0.35 as it was strong and flexible for the person with disabilities. And the process of manufacturing can be done as:

- Take the aluminum sheet and cut down the sheet to the size of 23 inches to make the lower stick.
- Cut the sheet in two angles form to make the underarm stick.
- Put the grip over the underarm stick
- Take the rubber pad and rotate it to make different cuffs.
- Attach the cuffs on the stick using the nuts.

7 IMPLEMENTATION

7.1 Manufacturing

For the manufacturing of device, we have decided to stay only with the CAD model, because implementation of this product is quite difficult as there are so many variations found in the body which cannot fulfill and need to have different dimensions for everyone. But the details about the manufacturing has given below.

First, need to buy the Stainless-Steel pipes, that will cut down into small pieces to make the crutches. Here are the items that will implement from the Stainless-steel pipes.

Table 6: Implementation Details

Implementation Parts	Quantity	Estimated Time of Manufacturing
Cuffs	**6**	**2 hours**
Bended Underarm Stick	**2**	**1 hour**
Bended Arm stick	**2**	**1 hour**
Stick	**2**	**1 hour**
Lower Stick	**2**	**1 hour**
Hand Grip	**2**	**1 hour**
Underarm	**2**	**0.5 hour**
Underarm Foam	**1**	**0.5 hour**
Hand Grip foam	**2**	**0.5 hour**
Leg Base	**2**	**1 hours**
Supporter Base	**1**	**6 hours**
Bracket	**1**	**1 hour**
Tires	**2**	**0.5 hour**
Wheel	**2**	**1 hours**
Break	**1**	**3 hours**
Break Rubber	**1**	**1 hour**
TOTAL HOURS		**22 Hours**

All the parts that will require the steel, will develop from stainless steel. Number of Cuffs are in round shape, so to make the round shape, will use the steel plate and then make it round.

Cut down the pipe into the pieces of stick and then fit the cuffs on the stick using the screws. Then fix the arm sticks using the screws on both sticks and then put the leg bases on both the crutches.

After that make, the support using the steel sheet and cut down the sheet same as given in the design and then fit the stick using the angle and attach the wheel on the stick by using the pin. In this way, the device will be ready to use.

To implement this device, it requires around 24 hours of consecutive work to make the parts and then assembling the parts will take around further 24 hours to finish the implementation. In this way, implementation of this device will take around 48 hours of work by the whole team.

After the implementation, it can test on different bodies to see the working of device and observe that the device is a hope device or not. This device is possible to wear by most of the common bodies because the updated design has leg bases which will keep the device stable.

7.2 Design Changes

Before the final implementation in CAD we have decided to make two crutches, one was for left and one was for right leg. Both crutches have different shape. Both crutches could be used in the other leg by replace the leg base. Left crutch was the main crutch which will provide the movement support and right crutch will be the on which person with disability will stand and take the support for forward movement. This design idea has been decided from the start but the basic changes we have done in the design are:

- We have decided to make four cuffs for left crutch, whereas we have decided already to make three crutches, but this change made in the design before the final implementation.
- Secondly, we have decided to put the left crutch long and it will reach to the underarm for supporting purpose. Before that we have decided to make the left crutch length same as right one, but this has changed.
- Another change made in the design is size of feet for both crutches. We have decided to make larger size of feet to make the crutches more stable and it will become easy to manufacture this device as well.

These were the two basic changes we have made for the final design. After these two-basic changed we have made into the design, we have decided to make another important change in the design. It has decided to add another support in the middle that will support the abdomen. This design change has greatly affected the complete design and the CAD model of this design has implemented. This new part has shown in figure 28 in the appendix B. And the changes made in the device legs have shown in figure 29 in the appendix B.

8 References

[1] U. California, “Controller Design and Implementation for a Powered Prosthetic Knee”, (Doctoral dissertation, University of California, 2012) (pp. 1-98). Berkeley, U.S.A: University of California. Retrieved February 26, 2018, from *http://digitalassets.lib.berkeley.edu/etd/ucb/text/Rosa_berkeley_0028E_12182.pdf*

[2] E. Axial, “Aluminum Axilla Crutches”, available [online], https://www.essentialaids.com/aluminium-axilla-crutches.html

[3] S. Hollister, “Exoskeleton to walk again”, March 2, 2013 published by CNET, available [online], https://www.cnet.com/news/cyberdyne-hal-exoskeleton-medical-rehabilitation/

[4] V. Medical, “Light Weight Walker”, available [online], http://www.viennamedical.com/c/walkers-canes-crutches.html

[5] A. Society, “Stainless Steel handles and Knobs”, available [online], https://www.indiamart.com/khodiyar-manufacturer/stainless-steel-handles-knobs.html

[6] M. Handles, “Wooden and Stainless Steel handles”, available [online], http://www.morehandles.co.uk/walnut-or-oak-and-stainless-steel-wooden-d-handle-h961.html

[7] B. Bunning, “prestige 16mm black plastic Round D”, available [online], https://www.bunnings.com.au/prestige-16mm-black-plastic-round-d-handle_p4026886

[8] A. Express, “Silver Tone Round Cuffs”, available [online], https://www.aliexpress.com/store/product/20pcs-Silver-Tone-316L-Stainless-Steel-Open-Round-Key-Holder-Split-Rings-Key-Chain-Key-Rings/1963165_32658673261.html

[9] R. Tools, “Stainless Rainwater Bracket”, available [online], https://www.roofing-tools.com/stainless-rainwater-pipe-bracket-square-c2x10638382

[10] R. Online, “Pro Brackets”, available [online], https://uk.rs-online.com/web/p/din-rail-terminal-accessories/0467343/

[11] S. Barbar, “Bases”, available [online], https://santabarbaradesigns.com/custom-components/bases/

[12] L. Lamina, “Accessory Base”, available [online], https://www.lamnia.com/es/p/6250/herramientas/kme-sharpeners-sharpening-system-accessory-base

[13] B. Bangs, “Shop Bases”, available [online], https://basilbangs.com/au/product/the-standard-umbrella-base/

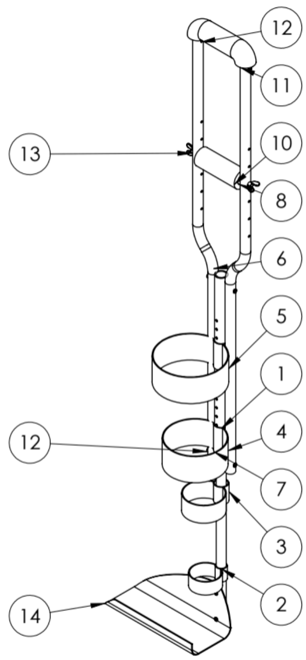
9 APPENDICES

9.1 APPENDIX A: Bill of Materials

Item #	Part Name	Qty	Material	Manufacturing Process	Cost	Store
1	Cuffs	6	Rubber	Chemical Formation	$60	https://www.grainger.com/
2	Hand Grip	2	Foam	Foaming	$10	https://www.grainger.com/
3	Lower stick	2	Aluminum	Aluminum Molding Process	$30	https://www.grainger.com/
4	Stick	4	Aluminum	Aluminum Molding Process	$30	https://www.grainger.com/
5	Bended Underarm Stick	2	Aluminum	Aluminum Molding Process	$50	https://www.grainger.com/
6	Bended Arm stick	2	Aluminum	Aluminum Molding Process	$40	https://www.grainger.com/
7	Underarm	2	Aluminum	Aluminum Molding Process	$30	https://www.grainger.com/
8	Underarm Foam	1	Foam	Foaming	$5	https://www.grainger.com/
9	Hand Grip foam	2	Foam	Foaming	$10	https://www.grainger.com/
10	Leg Base	2	Aluminum	Aluminum Molding Process	$20	https://www.grainger.com/
11	Supporter Base	1	Aluminum	Aluminum Molding Process	$5	https://www.grainger.com/
12	Bracket	1	Aluminum	Aluminum Molding Process	$15	https://www.grainger.com/
13	Tires	1	Rubber	Chemical Formation	$20	https://www.grainger.com/
14	Wheel	2	Aluminum	Aluminum Molding Process	$20	https://www.grainger.com/
15	Break	1	Aluminum	Aluminum Molding Process	$10	https://www.grainger.com/
16	Break Rubber	1	Rubber	Chemical Formation	$10	https://www.grainger.com/

9.2 APPENDIX B: CAD Model with Exploded View

CAD model has implemented for each part to explicitly show the dimensions and shape of each part.



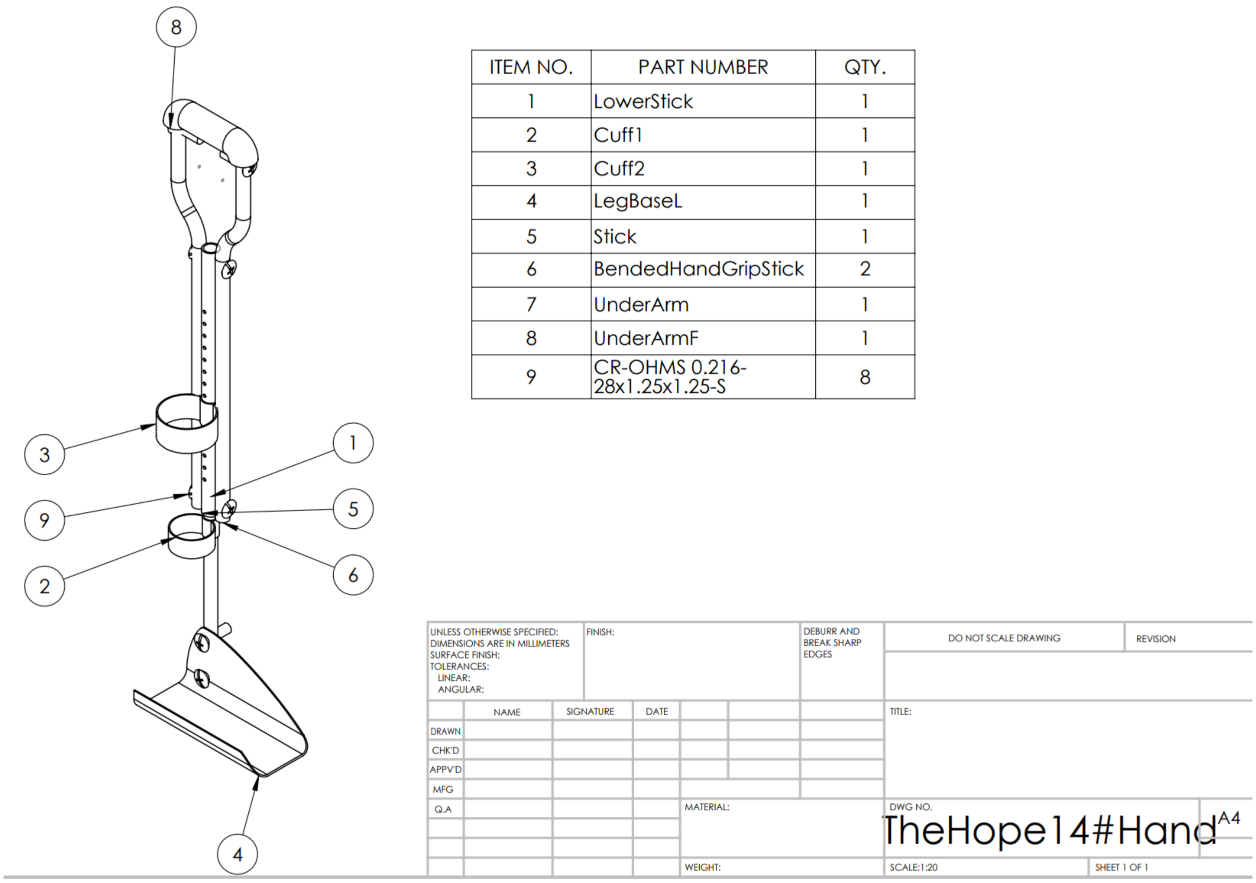
ITEM NO.	PART NUMBER	QTY.
1	LowerStick	1
2	Cuff1	1
3	Cuff2	1
4	Cuff3	1
5	Cuff4	1
6	BendedUndeArmStick	2
7	Stick	1
8	HandGrip	1
9	UnderArm	1
10	HandGripFoam	1
11	UnderArmF	1
12	CR-OHMS 0.216-28x1.25x1.25-S	8
13	1.25x0.25,Wing Screw,Type B,Style 2,Cup Point-S	2
14	LegBaseR	1

UNLESS OTHERWISE SPECIFIED:
DIMENSIONS ARE IN MILLIMETERS
SURFACE FINISH:
TOLERANCES:
LINEAR:
ANGULAR:
FINISH:
DEBURR AND BREAK SHARP EDGES
DO NOT SCALE DRAWING
REVISION

	NAME	SIGNATURE	DATE
DRAWN			
CHK'D			
APPV'D			
MFG			
Q.A			

TITLE:
MATERIAL:
DWG NO.
TheHope14#UnderArm
A4
WEIGHT:
SCALE:1:20
SHEET 1 OF 1

Figure 26: Right Crutch



ITEM NO.	PART NUMBER	QTY.
1	LowerStick	1
2	Cuff1	1
3	Cuff2	1
4	LegBaseL	1
5	Stick	1
6	BendedHandGripStick	2
7	UnderArm	1
8	UnderArmF	1
9	CR-OHMS 0.216-28x1.25x1.25-S	8

Figure 27: Left Crutch

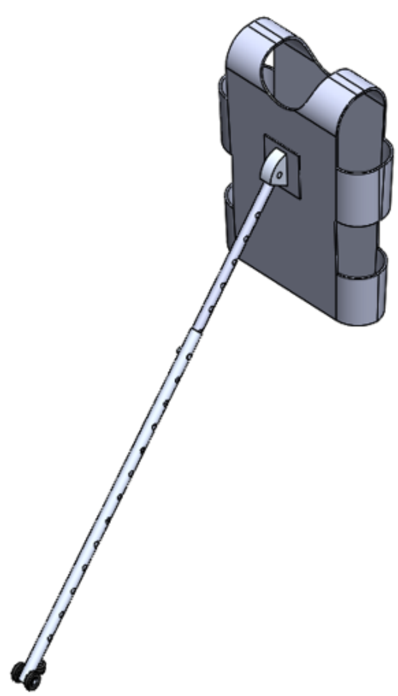


Figure 28: Third Support

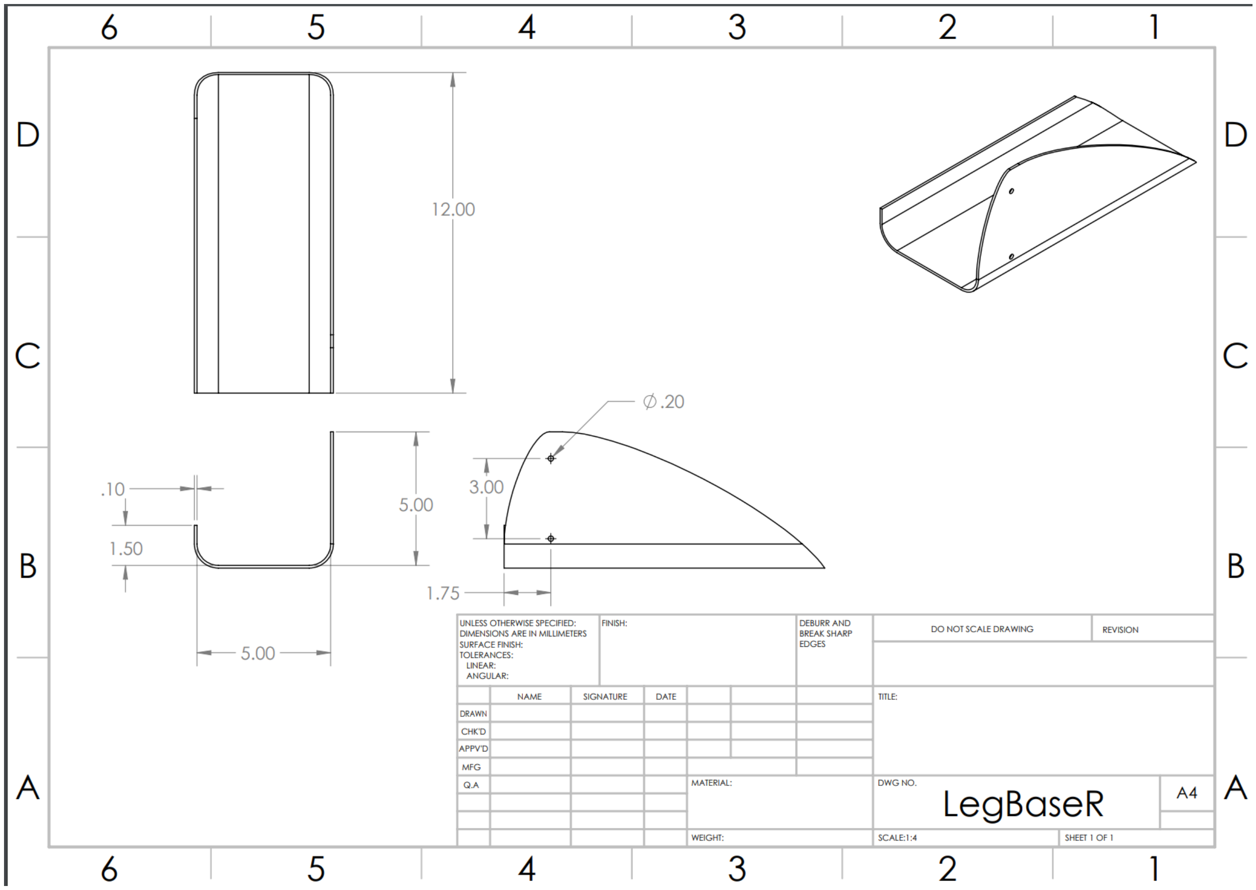


Figure 29: Legs Base